Strategies in empirical studies of swing groove

CARL HAAKON WADELAND

INTRODUCTION

'Swing' is a concept that many are likely to associate with jazz music. Indeed, one meaning of this notion of "swing" is used to denote a jazz style that developed in the United States during the 1930's. Among the most influential musicians from this period were Roy Eldridge, Coleman Hawkins, and "King of Swing" Benny Goodman. Dance music played by Big Bands became very popular during the swing period, and famous Big Band leaders were Duke Ellington, Count Basie, and Benny Goodman. Another meaning of 'swing' is related to rhythmic qualities of a music performance (originally, a performance of jazz music). Subject to this understanding swing, is conceived as a process through which the musicians, both individually and in an interactive context of playing together, make a musical phrase, a rhythm, or a melody 'come alive', by creating a performance that in varying degrees communicates motional aspects to the listener, thereby making the listener want to move along with the music. Or, as stated by the composer and jazz historian, Günter Schuller; a rhythm is perceived as swinging when: "…. a listener inadvertently starts tapping his foot, snapping his fingers, moving his body or head to the beat of the music." Seen as such, the qualities characterizing a swinging performance may be typical of musical performances belonging to other traditions than the jazz tradition, as well. Therefore, it also makes sense to assert that various performances of Bach’s “The Goldenberg Variations,” a Vienna waltz, a rumba from Cuba, a funk groove played by James Brown and Parliament, or a "springar" in Norwegian folk music may swing each and every performance in its own specific way.
A swing groove is a particular rhythmic ostinato played by jazz drummers. The swing groove originated in the swing era, but has been developed further in later jazz styles, like bebop and contemporary jazz. A typical swing groove is most often played on the ride cymbal. In its most basic form the swing groove may have the written representation illustrated in Figure 1.

Figure 1: An often used written representation of a swing groove.

Various performances of this swing groove often demonstrate interesting differences between different drummers. Typically, the drummer will perform the rhythm by making various deviations from the exact note values in the notation above. For example, some notes are played with shorter duration, other notes with longer duration compared to a strict "metronomic" (or, "deadpan") performance where each note is played according to the note values defined by musical notation. Furthermore, we may observe dynamical differences in dynamics among drummers, most noticeable in the distribution of accents on different beats in the swing ostinato. These various ways of swing performances may be highly individual for different drummers. In fact, the drummer may sometimes be identified by the way the swing groove is performed. It should also be noted that various performances of the swing groove may to different extent be musical appropriate (more or less "correct" related to various styles or traditions of performance), and may also in varying degree be swinging, i.e. make you want to ‘swing along with the music.’

Interesting investigations of performances of swing grooves in jazz have been presented by Rose, Reinholdsson, Pröglèr, Collier and Collier, and Friberg and Sundström. The main strategy in these studies has been to measure to what extent live performances show deviations from exact note values, and to relate these deviations to various musical/contextual parameters, such as tempo, individual preferences, and inter-ensemble relations (for instance rhythmic deviations between the musicians in an ensemble). A number of studies detecting various deviations in performances of groove-based music other than jazz have also been carried out, as well as in performances of western classical music.

Most research on rhythm performance has focused on investigating attack point rhythm, i.e. attack points (the temporal start point of a sound) and durations. However, for the performing musician attack points and durations are audible sounding consequences of continuous interactions between the musician, a musical instrument and different physical/social environments related to which the performance takes place.
When the drummer rehearses swing grooves, it is necessary to practice coordination of hands and feet, and to be able to coordinate movements of drumstick, hand and wrist. The aim of this training is to develop various movement strategies for relaxed and flexible performances of swing groove. To obtain a more comprehensive understanding of various interactions of the parameters underlying the characteristics of a rhythm performance it is, therefore, necessary to take gestural aspects of the performance into account in addition to the study of attack point rhythm. A major focus of the present investigation is to apply a combination of movement studies and attack point detection in order to achieve analytical insight into different drummers’ performances of swing groove. To demonstrate this approach I will now:

a) Present the design for an empirical investigation of swing performance.
b) Outline results from a case study which exemplifies various interactions of performance parameters.
c) Discuss our findings and point at some further possible developments of our approach.

The strategy of investigation that we here propose is in our present study applied to the investigation of performance of swing groove in jazz. However, by the nature of the experimental design, this approach could just as well, with some modifications, be applied in empirical studies of music performance on a more general basis.

EXPERIMENTAL DESIGN

Our approach in this empirical study is to apply a combination of gestural and attack point analyses of rhythm performance. The experimental method and the equipment used for the collection of empirical data are both described below, and are well known within empirical movement science. The setup for this empirical experiment has also been reported in some earlier publications by the author.6

Subjects:
The subjects participating in this experiment are semi-pro/professional drummers acquainted with jazz drumming. All of the drummers were, at the time of the experiment, students or teachers at Section of Jazz Education, Department of Music, NTNU.

Task:
The subjects were asked to use one drumstick to play swing grooves restricted to various performance conditions that are defined in relation to:

- Tempo: 7 different tempi, ranging from 60 bpm (beats per minute) to 300 bpm.
Accents: The subjects were asked to play three different versions of the swing groove with accent on the first, second and third note, respectively, in the swing pattern.

Swing ratio: I.e. various rhythmic subdivisions of the quarter note pulse (more about this in the next section).

Equipment:
The measurements were carried out assisted by Geir Oterhals, Section of Movement Science, NTNU. Figure 2 illustrates how the experimental situation was constructed. The figure shows the drummer playing on a “force plate” using one drumstick. Markers were placed on the drummer’s arm and on the drumstick.

Figure 2: Illustration of experimental setup for measuring gestural and attack point aspects of performance of swing groove.

For our setup the following components were applied:

- 6 cameras (Proreflex camera system) transmitting infra red light were used to measure movements of the arm and the drumstick (kinematics). Sampling frequency = 240 Hz.
- 5 markers reflecting the light were placed on the drummer’s shoulder, elbow, wrist and hand, as well as on the drumstick.
- A force plate (Kistler) measuring force from the drumstick was used to give accurate measurements of attack points. Sampling frequency = 960 Hz.
- A minidisk was used for audio recording of the experiment.
A similar experimental approach as the one we here describe has been used by Mårds in her study of movements in Norwegian folk dance, and Dahl in her investigation of different drummers' strategies in the performance of an accent in a series of drum beats. Before we outline some results from our study we first present some rhythmic parameters that will be needed in our later discussion.

**SOME BASIC PARAMETERS IN STUDIES OF SWING PERFORMANCE**

*Swing ratio:*

As mentioned in the introduction, various performances of a swing groove may show interesting differences among different drummers. One aspect of the variety of individual swing performances is related to the relative temporal placement of the beats in the swing pattern. To discuss this one often points at differences in performances by classifying the swing performances as being (more or less) close to one of the three written representations of the swing groove displayed in Figure 3.

*Figure 3: Three different notational categories representing a swing groove.*

As shown in Figure 3 we have labelled the beats of the swing pattern $b_1$, $b_2$, $b_3$, $b_1'$, $b_2'$, $b_3'$ in order to be able to distinguish between different repetitions, or different cycles, in the 3-beat cyclic pattern ($b_1$, $b_2$, $b_3$). – In the literature on empirical studies of mu-
sic performance the duration from the beginning of a tone to the beginning of the next
tone is often called the *interonset interval*, IOI (or $d_{ii} =$ duration in-in). In our situat-
on IOI = the time between successive attack points, marked by the drumstick hitting
the cymbal (or, in this experiment: the drumstick hitting the force plate). For our follo-
wing discussion the term *duration*, $d$, of a beat is used to refer to the IOI between the
beat and the next beat, and we let:

$$
\begin{align*}
    d_1 &= \text{duration of beat } b_1 = \text{IOI}(b_1, b_2) \\
    d_2 &= \text{duration of beat } b_2 = \text{IOI}(b_2, b_3) \\
    d_3 &= \text{duration of beat } b_3 = \text{IOI}(b_3, b_1)
\end{align*}
$$

We now make the following definition:

*Swing ratio* (SR):

$$
\text{SR} = \frac{d_2}{d_3}
$$

and we observe that a performance in *strict* accordance with (I), (II) and (III) in Figure
3 represents, respectively:

- SR = 1; i.e. eighth note subdivision,
- SR = 2; i.e. eighth note triplet subdivision,
- SR = 3; i.e. sixteenth note subdivision of the quarter note pulse in the 4/4
  swing pattern.

*Real* performances, however, typically show various deviations from the notation in Figure
3. Or, to make a more relevant statement, it is really *the other way around*: None of the three
versions of notation given in Figure 3 has at any time been an ideal for the experienced jazz
drummer. The ideal is the swinging performance in itself, whereas the various written no-
tations are only different representations of an *approximation* to some aspects of the jazz
 drummer's performance of swing. In this respect the performance is *not* characterized by
deviations from note values, on the contrary, it makes more sense to say that the various
written notations, in greater or less degree, *deviate from the reality of music performance*.

Investigations of jazz drummers’ swing ratio have been undertaken by Prögler, Col-
lie and Collier, and Friberg and Sundström. The most consistent findings in this re-
spect have been reported by Friberg and Sundström. They used three well-known jazz
recordings and a play-along record (the drummers on these recordings were Tony Wil-
lams, Jack DeJohnette, Jeff Watts and Adam Nussbaum). A main focus of Friberg and
Sundström was to study the influence of tempo on swing ratio, and they found that the
swing ratio varied linearly with tempo, ranging from SR = 3.5 at slow tempi (about 100
bpm), to SR = 1 at fast tempi (about 300 bpm).
Accentuation:
Apart from variations in swing ratio different jazz drummers may apply different distributions of accentuation in their performance of the swing groove. The three possible 3-beat cyclic patterns of accents are shown in Figure 4. Note that for the discussion of accentuation we here choose to write the swing groove with sixteenth note subdivision, even though various performance of accentuation may have different effects on the swing ratio. This will become apparent later in our presentation.

Figure 4: The three possible 3-beat cyclic patterns of accents in the swing groove.

(i)

(ii)

(iii)

Of the three possibilities illustrated in Figure 4, (ii) and (iii) are, by far, the most common. Indeed, the alternative (i) would within the tradition of jazz drumming in most cases be considered as inadequate and non-swinging. To our knowledge there does not seem to be much research done on the various effects of different patterns of accentuation in swing performances. However, interesting studies of performance of the accent in a series of drum strokes have been carried out by Dahl, e.g. reporting that the interval beginning with the accented stroke tended to be prolonged.\(^\text{13}\)

RESULTS FROM A CASE STUDY
We now present some results from a case study where we apply a combination of movement detection and timing analysis in order to investigate interactions between gestural and attack point qualities of rhythm performance. All graphical illustrations as well as
analyses of movement and timing are done in Matlab. – In the example below we make comparisons between a “neutral” performance of swing and a performance where some additional playing conditions are imposed.

The neutral situation: Experiment (N):
The subject, S, is asked to play swing groove on the force plate at tempo 120 bpm as natural and comfortable as possible. To establish the tempo a metronome is used, but when S affirms to feel the tempo and is ready to play, the metronome is turned off and S starts to play the swing groove without any accompaniment by the metronome. The performance lasted for 15 seconds. Figure 5 shows the vertical movement (height vs. time) of drumstick, hand and wrist, respectively, of one representative section in this performance of swing groove.

Figure 5: Vertical movement of drumstick, hand and wrist in a performance of swing groove.

Gestural aspects of the performance:
From the illustration in Figure 5 we observe:

1. The movements of drumstick, hand and wrist all show rather cyclic/periodic-like movement patterns, indicating “a certain way of moving” in this particular performance of the swing groove.
2. On \( b_2 \) and \( b_2' \) the drumstick strokes precede the minima of hand and wrist movements.

3. \( b_1 \) and \( b_1' \) are performed with the hand and wrist moving upwards, preparing strokes on \( b_2 \) and \( b_2' \).

It should at this point be emphasized that whereas Figure 5 displays the vertical components of the movements of drumstick, hand and wrist, it is important also to take into account the components perpendicular to the vertical axis (i.e. “sideways” and “back and forth” movements). We will return to a discussion of how the movement components in the horizontal plane might influence timing and sound producing aspects of drumming in the closing section of this presentation. For now, we bear in mind this remark when we look at some further interesting observations that can be made on the basis of the vertical components of the movements.

Kinematic data characterizing the vertical movement of the drumstick in two representative measures (measures 3 and 4) of the performance are shown in Figure 6.

Looking at Figure 6 we see:

4. The graphical representation of displacement, velocity and acceleration all reflect a high degree of consistency in this performance of swing groove. The 3-beat cyclic pattern \((b_1, b_2, b_3)\) is to a large extent performed “in the same manner” throughout the performance. This observation should not be very surprising. The subject, S, is a well-trained musician acquainted with jazz drumming. Playing swing groove with a jazz band on a concert requires the ability to maintain (various variations of) the swing groove interesting and groovy for a long period of time. To be able to do this the drummer has to spend hours rehearsing in order to internalize a way to play the groove in a relaxed and efficient way, without having to reflect upon how the groove should be played. It is therefore to be expected that the confident jazz drummer has developed a repertoire of “automated” performance strategies, and is able to apply these in order to obtain consistent and groovy performances adapted to various conditions imposed by the musical environments subject to which the performance takes place.

5. We make the following definition:

\[
\text{Preparatory height (hp) for a beat } b_n = \text{Largest vertical displacement of drumstick in the preparation for the performance of beat } b_n,^{14}
\]

and we observe that:

\[
h_p(b_1) < h_p(b_3) < h_p(b_2)
\]

for all cycles of \((b_1, b_2, b_3)\) in Figure 6 (this is also observed for all cycles of \((b_1, b_2, b_3)\) in the entire time span of this particular performance). Furthermore, we note that this relation between preparatory heights reflects the length of the interonset intervals between the beats:

\[
\text{IOI}(b_3, b_1') < \text{IOI}(b_2, b_3) < \text{IOI}(b_1, b_2),
\]
STRATEGIES IN EMPIRICAL STUDIES OF SWING GROOVE

Figure 6: Illustration of kinematic data from detection of vertical movement of drumstick in a performance of swing groove. From bottom to top: Displacement, velocity, acceleration.
which seems quite natural: Since, e.g., IOI(b₁, b₂) is the largest, the drummer has more time to raise the drumstick in the preparation for the performance of beat b₂, as compared to the performance of beat b₁ and b₃.

6. If we, moreover, define:

\[ v_n = \text{velocity at the attack point of } b_n \]
\[ a_n = \text{acceleration at the attack point of } b_n, \]

we find that for all cycles of (b₁, b₂, b₃ ) in Figure 6:

\[ \text{abs.val}(v_1) < \text{abs.val}(v_3) < \text{abs.val}(v_2) \]

and also:

\[ (*) \quad a_1 < a_3 < a_2 \]

Thus, in this Experiment(N) both the absolute value of velocity and the acceleration are ordered in magnitude in the same way as preparatory height and interonset intervals. – Since classical mechanics tells us that force is proportional to acceleration, (*) implies that if \( F_n = \text{striking force at the attack point of } b_n, \) we get:

\[ F_1 < F_3 < F_2, \] for all cycles of (b₁, b₂, b₃ ).

In other words; in the neutral situation defined by Experiment (N), the subject performs the swing groove in a consistent manner with most (dynamic) emphasis on b₂, least emphasis on b₁. Thus, the performance is in accordance with alternative (ii) in Figure 4. Moreover, this distribution of relative dynamics is reflected in the distribution of preparatory heights.¹⁵

**Timing analysis:**

For timing analysis we measure the IOIs, which can be found by the registration of attack points given by the drumstick hitting the force plate. Figure 7 shows the durations, \( d_1, d_2, d_3, \) for all cycles of beats (b₁, b₂, b₃ ) over a period of 4 measures (measures 3–6).

Figure 7: Display of durations, \( d_1, d_2, d_3, \) for 3-beat cycles (b₁, b₂, b₃ ) over a period of 4 measures.
STRATEGIES IN EMPIRICAL STUDIES OF SWING GROOVE

We now find:

7. \((d_2 + d_3) > d_1\) for all cycles \((b_1, b_2, b_3)\) of beats. – This means that of the four pulse beats in the 4/4 swing pattern (cf. Figure 3) this performance shows a prolongation of the second and forth quarter note pulse beat (the pulse beats that are subdivided by \(b_2\) and \(b_3\)) as compared to the performance of quarter notes on the first and third pulse beat. It is also interesting to note that Figure 7 demonstrates a pattern indicating a slight tendency of alternating longer-shorter durations in the \(d_2\)'s.

8. If we calculate the swing ratio, \(SR=(d_2/d_3)\), and find the average value (arithmetic mean) over the 8 pairs of \((d_2, d_3)\) in Figure 7, we get:
\[
\text{Mean}(SR) = 2.10, \text{ with standard deviation } = 0.10.
\]
This reflects a fairly consistent triplet-close subdivision in this swing performance, slightly to the sixteenth note side.

In the presentation above we have outlined some findings that show characteristic gestural and timing aspects of a performance of swing groove made by the subject S in a “neutral” situation. It is expected that, within the limits of the experimental situation, this performance is an approximation of how S would perform a basic swing pattern in tempo 120 bpm in a non-experimental live musical situation. (We will make some comments upon this statement in the closing discussion of this paper.) Given the results from Experiment(N) we now conduct a new series of experiments where we impose some additional playing conditions, and we address the following basic question:

How do these additional conditions affect the performance compared to the (neutral) situation in Experiment(N)?

To illustrate our approach we now present some results from the following experiment:

Experiment(Acc3): Accentuating every third beat in the swing cycle:
The subject, S, is asked to play the swing groove on the force plate at tempo 120 bpm making an accentuation on every \(b_3\) in the swing cycle (i.e. in accordance with alternative (iii) in Figure 4). As before, a metronome is used to establish the tempo, and the metronome is turned off when S is ready to play. This performance also lasted for 15 seconds. It should here be noted that in remark (6) in the discussion of Experiment(N) we found that the most natural way for S to perform the swing groove (given the experimental setup) is to make a slight accentuation on every \(b_2\) in the swing cycle. Thus, the task given in Experiment(Acc3) does contain additional performance requirements compared to Experiment(N), and the question is: In comparison to the neutral situation: To what extent are movement patterns and timing qualities changed by the influence of this additional condition?
Movement patterns:
A comparison between vertical movement of drumstick, hand and wrist in Experiment(Acc3) and the neutral situation is shown in Figure 8.

Figure 8: Vertical movements of drumstick, hand and wrist in Exp(Acc3) (top) and Exp(N) (bottom).
Looking at Figure 8 we observe:

1. The periodic-like movement patterns in the two experiments show remarkable differences. First of all:
   \[ h_{p}(b_3) \text{ in Exp(Acc3)} > h_{p}(b_3) \text{ in Exp(N)}, \]
i.e. when the subject is asked to make an accentuation on \( b_3 \), \( S \) performs the accent by raising the drumstick higher above the striking surface in the preparation for the accented stroke, thereby giving the drumstick larger (downward) velocity and acceleration at the attack point of \( b_3 \), cf. also Figure 9 which shows the vertical acceleration of the drumstick in Experiment(Acc3). This change in preparatory height for the accented stroke has also a major effect on the preparatory height for the stroke preceding the accent:
   \[ h_{p}(b_2) \text{ in Exp(Acc3)} < h_{p}(b_2) \text{ in Exp(N)}. \]
   That is to say, whereas \( b_2 \) is performed with a slight accentuation in the neutral situation, the condition of accentuating \( b_3 \) makes \( S \) play \( b_2 \) softer, which requires less preparatory height, \( h_{p}(b_2) \), in Experiment(Acc3) as compared to Experiment(N). (This can also be seen in Figure 9.) On the other hand, the preparatory height for \( b_1 \) is not much affected by the additional performance condition of Experiment(Acc3).
2. In Experiment(Acc3) we see that the preparatory heights reflect the distribution of accents, but does \textit{not} reflect the length of the IOIs (as was the case in the neutral situation, cf. (5) in the discussion of Experiment(N)).
3. Observing hand and wrist movements in Figure 8, we see that in Exp(Acc3) the hand and wrist have started an upward movement on b₂, preparing the accented stroke on b₃, whereas the hand and wrist movements on b₂ in Exp(N) are downward. Moreover, in Exp(Acc3) there is minor vertical movement of hand and wrist on b₁, as opposed to Exp(N) where hand and wrist have started an upward movement on b₁ in preparation for the (slightly) accented stroke on b₂.

**Comparison of timing:**

Figure 10 illustrates the durations, d₁, d₂, d₃, for all cycles of beats (b₁, b₂, b₃) over a period of 4 measures (measures 3–6) in Experiment(Acc3).

**Figure 10:** Display of durations, d₁, d₂, d₃, for 3-beat cycles (b₁, b₂, b₃) over a period of 4 measures in Exp(Acc3).

We observe:

4. Calculating swing ratios and averaging over the 8 pairs of (d₂, d₃) in Figure 10, we find:
   - Mean(SR) = 1.83, with standard deviation 0.19.
   - This reflects a performance that is *not quite as consistent* as the performance in the neutral situation. The subdivision is still triplet-close, but now somewhat to the eighth note side.

5. We still find that (d₂ + d₃) > d₁ for all cycles (b₁, b₂, b₃). In fact, this inequality is *enlarged* (in Experiment(Acc3) we find that Mean(d₂ + d₃) / Mean(d₁) = 1.08, as compared to 1.03 in Experiment(N)).

6. Moreover, we note that there is an overall interesting tendency in Experiment(Acc3) indicating that a noticeable effect of accentuation is that the duration of the accented beat is *lengthened* in comparison to the neutral situation. This is demonstrated in
Figure 11. – To understand this figure it is important to be aware of that even though a metronome with 120 bpm was used for establishing the tempo in both experiments, the metronome was turned off when S started to play. This caused a slight drift in tempo during the performance. To be able to compare timing in the two experiments we therefore calculate durations as percentages of measure length (where, e.g., a metronomic performance of a quarter note in a 4/4 measure would have a length-percentage of 25%, an eighth note 12.5% etc.). To give an overall picture of how accentuation affects the distribution of durations in swing performance, Figure 11 displays the mean value of durations as percentages of measure length, calculated over 4 measures (measures 3-6 in both experiments). We observe that the general tendency is that the lengthening of interval 3 takes duration from both intervals 1 and 2. This is also reflected in the transformation of swing ratios:

In the neutral situation: Mean(SR) = 2.10, whereas:
In Experiment(Acc3): Mean(SR) = 1.83.

Figure 11: Mean value of durations as percentage of measure, a comparison of Exp(N) and Exp(Acc3).

Conclusions for this case study:
In this case study we have conducted a “neutral” Experiment(N) and, given knowledge of the findings from Experiment(N), we have posed the following question:

In comparison to the neutral situation: In what ways are movement patterns and timing qualities in the swing performance affected by the influence of the additional performance condition given in Experiment(Acc3)?
Within the experimental setup and on the basis of swing performances made by the subject S, we have reached the following answers to this question:

The additional playing condition given by asking S to make an accentuation on every b₃ in the swing cycle has:

a) Major effect on movement patterns/movement strategies in the performance. In particular this is noted in relation to:
   – preparatory heights reflecting the distribution of accents and relative dynamics
   – hand and wrist moving upwards on the beat preceding the accent

b) Noticeable effect on timing, especially we find:
   – The duration of the accented beat in Experiment(Acc3) is lengthened as compared to the neutral situation. The overall tendency is that this lengthening of d₃ "takes duration" from both d₁ and d₂.
   – The swing ratio is altered when S makes an accentuation on b₃.
   – The occurrence of alternating shorter-longer durations of the quarter note pulse beats in the neutral situation is strengthened in Experiment(Acc3).

The findings of this case study will be commented further in the discussion below.

DISCUSSION

Our main intention in this paper is to present a new strategy in empirical studies of music performance, with special focus on the performance of swing grooves in jazz. The approach of investigation that we here propose, involves combining movement registration and attack point detection of a performance that takes place within a specified experimental setup. There should be made some comments to this strategy:

1. How natural is "neutral"?

A basic idea in our experimental setup is to start by making registrations of performance data in a “neutral” situation, Experiment(N), after which the registration of data from experiments involving various additional performance conditions are compared to the neutral experiment. It seems at this point relevant to ask: How neutral, not to say natural, is the “neutral” experimental situation? Obviously, a more natural playing condition in our investigation of swing groove performance would be to ask S to play the groove on a ride cymbal instead of on a force plate. The main reason for using the force plate is that this performance makes possible a more accurate detection of attack points needed for timing analysis than does a performance on a cymbal. In order to find out to what extent this experimental neutral condition is representative for a specific natural situation, we need to make a comparison between movement curves of force plate vs. cymbal performances. At this point it should also be mentioned that some of the subjects participating in the experiments commented
that they would feel more comfortable playing the swing groove if they were allowed to use the whole drum set; “filling-in” on the snare, bass drum, and hihat underneath the ride cymbal swing pattern. All this said, it is here important to emphasize that “neutral” should not be confused with, nor be seen as synonymous with, “natural”. The conditions given in Experiment(N) define the neutral experimental situation. These conditions are by definition taken as references in the comparison with performances that are made subject to other performance conditions than those characterizing Experiment(N). The definition of the neutral situation is subject to a choice made in relation to the design of our experiment, the choice being that Experiment(N) should come as close to a natural playing situation as possible, given the constraints of the experimental setup. We do not at any point assert that Experiment(N) represents any specific natural situation. Instead, we make comparisons between different experiments to see how various performance parameters interact within the conditions of the experiment, – inside the experimental situation, – and we suggest that it is likely that characteristics of various interactions of performance parameters that are detected within the experiment, will have validity also in the real, “natural” world of music performance – outside the constraints given by the experimental setup.

2. From vertical to 3 dimensions:
In our presentation the main focus has been on the vertical displacement of drumstick, hand and wrist. Even though the vertical movement of the drumstick is often regarded as making the main contribution to the sound-producing aspects of drumming (at least when the striking surface is horizontal), it is also important to consider the components perpendicular to the vertical axis, i.e. “sideways” and “back and forth” movements. Figure 12 shows a 3-plot display of 2 measures of drumstick movement in the neutral situation, illustrating vertical (z), sideways (x), and back and forth movement (y), respectively, whereas Figure 13 shows the same section of drumstick movement in a 3-dimensional display, seen from two different angles.
Figure 12: Movement of drumstick in a performance of swing grove, $Exp(N)$ Displayed in 3 dimensions; from top to bottom: Vertical ($z$), Sideways ($x$), Back and forth ($y$).
Looking at Figure 12 it is interesting to observe that also the sideways and the back and forth movements show periodic-like patterns (especially the back and forth movement). In the excerpt shown in Figure 12 we note, for instance, that the attack points of the drumstick are pulled slightly backwards (1.5–2 cm) in the performance of every
(b₂, b₃, b₁')-cycle. Both Figure 12 and Figure 13 illustrate that the drumstick strikes the force plate (or, in the analogous “real” situation: the cymbal) at different places (roughly within an ellipse with axes 3cm x 2cm), with different angles of attack direction, and this is done in a periodic-like manner. Thus, the xy-components of the drumstick movement contribute to make the different beats in the swing cycle sound different, which, blended with the contribution of the vertical component can make it possible to identify the different beats in the swing cycle on the basis of differences in the timbre of the sound.

3. From one to many
All together, 10 drummers participated as subjects in this investigation. We have here presented only a case study involving one subject performing one task (apart from the neutral situation). A natural further development would be to study which interactions of performance parameters are common among drummers that share a common reference for traditions of drum performance. Apart from studying the influence of accentuation on movement patterns and timing, it is also interesting to investigate, e.g., the influence of tempo on movement strategies and dynamics. These matters will be focused in our forthcoming studies of swing performance.

4. Applications of results
On a general level, this investigation may contribute to develop a new methodology in the study of music performance: Instead of measuring only attack points and durations, a description of music performance as a continuous process taking gestural aspects into account, is offered. Moreover, analysis of interactions between gestural and attack point data will help to provide new insight into basic features of rhythm performance, which will have interesting pedagogical applications, and thus be of interest to musicians and music teachers. It should also be noted that the findings of this empirical investigation are important for the construction of continuous (computer) models generating synthetic rhythm performances that approximate reality. One such model is developed by the author. It seems likely that results derived from these experiments will be valuable in the further development of this model.

ACKNOWLEDGEMENTS
The author is very grateful to Geir Oterhals for fruitful assistance and cooperation in the measurements of rhythmic movements, and to Gertjan Ettema for help with Matlab applications for movement analysis. Special thanks are due to the drummers participating in the experiments. The author also thanks an anonymous reviewer for comments on an earlier version of this document. Economical support to part of this project was provided by The Faculty of Arts, NTNU.
Notes
1 Part of this paper was reported by the author in an oral presentation at the research seminar: "Rhythm and Micro-rhythm: Investigating musical and cultural aspects of groove-oriented music", University of Oslo, September 22–24, 2005.
7 Mårds (1999).
10 This definition of swing ratio is in accordance with Friberg & Sundström (2002).
12 Friberg & Sundström (2002).
14 This definition is in accordance with Dahl (2004).
15 Dahl (2004) also reports that the drummers in her experiment raised the stick to a greater height in preparation for the accented stroke.
16 A similar result is documented by Dahl (2000, 2004) in her study of drummers’ performances of a series of beats on a drum, where every forth beat is accentuated.
18 See Waadeland (2001).

References
CARL HAAKON WADELAND


Summary

A major focus of the present investigation is to apply a combination of movement studies and attack point detection in order to achieve analytical insight into different drummers’ performances of swing groove. To demonstrate our approach we present the design for an empirical investigation of swing performance and outline some results from a case study which exemplifies various interactions of performance parameters. Moreover, we discuss our findings and point to some further possible developments of our approach. The strategy of investigation that we propose is in our present study applied to the investigation of performance of swing groove in jazz. However, by the nature of the experimental design, this approach could just as well, with some modifications, be applied in empirical studies of music performance on a more general basis.

Key words

Swing performance, Movement, Timing, Empirical study

Biography

Carl Haakon Waadeland is Associate Professor at Department of Music, Norwegian University of Science and Technology (NTNU) in Trondheim, where he is engaged in jazz education and music technology. He finished his PhD (Dr.art.) at NTNU in 2000 with a thesis on rhythmic movement and moveable rhythms.
Waadeland is a drummer and has participated on a large number of CD’s, concerts and festivals, amongst others with Gay Holton & Casino Steel, Warne Marsh, Henning Sommerro, Åge Aleksandersen & Sambandet, Siris Sval Band, Mikis Thodorakis & Arja Saijonmaa, and Dadafon.
In 1991 Waadeland published a book on rhythmic movement and moveable rhythms, Trommelslåtter – en trommeslagers skattekiste, with an accompanying CD where an old Norwegian folk drum tradition is presented.